Understanding regular variability in magma composition and eruption frequency through high-precision, long tephra records

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It has long been recognized that reawakening stratovolcanoes have a semi-regular pattern of activity, with return periods of large, destructive eruptions at many volcanoes around the world on the order of 200-500 years. This may be driven by magma-production rates, heat flow or mantle fertility of various volcanic settings, or simply represent the time taken for the filtering and processing of magma as it makes its way through the crust to eruption. Plaguing the quest for a deeper understanding of the processes leading to regular large eruptions at stratovolcanoes is the need for a complete record of volcanic output over time. We attempt to fill this gap by building the highest possible resolution records of volcanic activity for the longest possible periods at individual volcanoes. We present here our results from two tephra records containing more than 160 eruption events, one from Mt. Taranaki, New Zealand that extends for 32 ka and the other from Gunung Merapi, Java, Indonesia that spans 10 ka. Both records show regular variations in dome-building vs. explosive eruptions, the former represented by fall and surge layers dominated by dense juvenile lithics and the latter by lapilli-dominated pumice fall and pyroclastic flow deposits. Both records also show regular cycles in variations of eruption frequency. Glass and titanomagnetite chemistry (via Electron microprobe) shows regular variations in erupted composition that match with eruption frequency cycles. Titanomagnetite Ti, Al and Mg contents show strong correlation with eruption style and frequency. Mg and Al contents of titanomagnetite and glasses of each record indicate cycling between the eruption of mafic and evolved andesitic magmas. Variability in Ti concentrations primarily reflects late-stage solid-state exolution in magmas stored in shallow conduits and domes. By contrast, homogenous Ti, Al and Mg contents of titanomagnetites reflect the initial partial melting, fractional crystallization, assembly and mixing of multiple magma sub-batches at mid to lower crustal depths before sudden eruption via sub-plinian processes. Contrasting in these two records, however, is the overall frequency of eruptions and the nature of long-term geochemical changes. The Taranaki system shows an increasing average Ti content in titanomagnetites, corresponding with higher alkali (especially K) contents in glasses and whole-lapilli compositions. By contrast, the Merapi system appears relatively more stable over time. Comparing and contrasting these two long records, along with the assembling of similar detailed eruption sequences at other stratovolcanoes, can provide improvements to the hazard assessment at such volcanoes through the more robust informed application of probabilistic methods. This research direction can also provide new insights into the magmatic and eruptive dynamics of stratovolcanoes, and especially transitions between various eruption mechanisms and magnitudes.